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A report for land managers on recent developments in forestry research at the four western Experiment Stations of the Forest Service, U.S. Department of Agriculture

In This Issue

Cover

Researchers at the Pacific Northwest Station are studying the habitat needs of anadromous salmonids along the West Coast. This scientist is recording water temperature near a net that collects drifting insects. Over the years, populations of these fish have declined due to increased harvest and destruction of habitat. The Forest Service and several other cooperators are hoping to turn the tables. Read more about it on the facing page.

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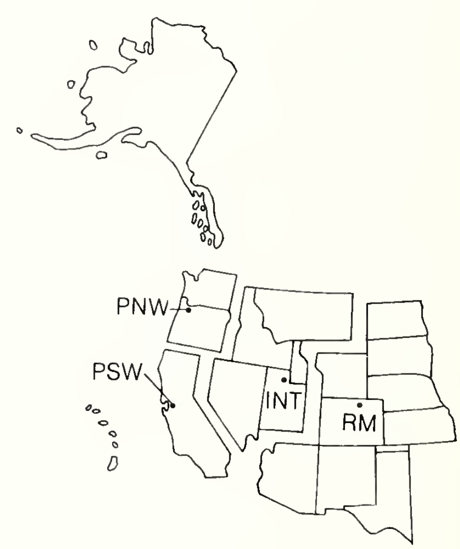


Understanding the habitat needs of anadromous salmonids

by Dorothy Bergstrom, Pacific Northwest Station

A researcher collects terrestrial insects that have dropped into a floating trap.

Along the West Coast of North America, from California to Alaska, the many rivers and streams that empty into the Pacific Ocean are habitat for a unique and valuable resource—the famous sea-run salmon and trout—or anadromous salmonids.

This region produces eight species, including five salmon—chinook, coho, chum, sockeye, and pink; two trout—steelhead and cutthroat; and one char—Dolly Varden. These migratory species have evolved a complex reproductive process that requires two habitats—fresh water streams and lakes and the Pacific Ocean. Some fish travel hundreds or even thousands of miles and spend virtually their entire lives in instinctive migration from fresh water tributary to salt water and back again.

But over the years, fewer and fewer fish have made the journey. Increased harvest of fish and destruction of habitat have reduced the yield dramatically. Both the size of catches and the size of fish have become smaller. The weight of concern about habitat loss rests heavily on managers of forests and rangelands—since the freshwater rivers and streams that flow through these lands provide important habitat for spawning and rearing. And because streams ultimately reflect everything that happens in watersheds, all management activities have the potential for affecting fish habitat.

Providing information that will help resource managers predict the effects of management activities on the welfare of fish is the purpose of a new series of publications collectively titled "Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Western North America." The report series is one of the products of an interagency program established in 1976. Three Forest Service Experiment Stations and five Forest Service Regions are cooperating with several federal and state agencies, universities, and private industries in a program to coordinate research concerning fish habitat and report results to managers.

Fisheries Biologist Bill Meehan of the Pacific Northwest Station's Forestry Sciences Laboratory in Juneau, Alaska, is coordinator of the program. "While we have learned a good deal about anadromous salmonids," he says, "the knowledge has been scattered in scientific publications and has not been readily available to resource managers. One of the goals of the program is to pull together results of research concerning habitat needs and the effects on habitat of forest and rangeland management." Four reports have now been published. Ten more are planned.

Habitat needs

The first report lays the foundation for the series. It defines the range of conditions that allow the 8 major species of anadromous salmonids to thrive, thereby providing standards against which the effects of management activities on habitat can be measured.

Western anadromous salmonids are adapted to a variety of habitat conditions within their range. Most species have distinctly different life histories and habitat requirements. Certain conditions, such as water temperature, velocity, turbidity, and the amount of dissolved oxygen in the water are important at all life stages. Other requirements are important at certain life stages. For example, migrating adults making the journey to their birth streams from the sea need streams that are free from barriers. After the adults arrive in their home waters, they need hiding cover during the weeks or months while they look for satisfactory places to build their redds (nests). While the eggs are incubating, conditions within the stream bed gravels determine whether fry will hatch successfully. After the fry emerge from the gravel, their greatest needs are for food, cover, and space.

Water temperature

Salmonids are cold water fish and prefer a rather narrow range of temperatures. Tolerances and preferences of the species vary somewhat, but scientists working in laboratories and artificial streams at research facilities along the Pacific Coast now have good information about temperature requirements.

Salmonids have successfully migrated upstream in temperatures ranging from 3° to 20°C. Temperatures above 20°C have been found to stop migration, alter the timing of migration, accelerate or retard maturation, and lead to outbreaks of disease. Spring chinook salmon tolerate the lowest range. They migrate best in water that is between 3.3°C and 13.3°C. Summer chinook salmon are at the other end of the scale, doing well in a range from 13.9° to 20°C.

Temperature Comparisons

Celsius °	Farenheit °
0	32
5	41
10	50
15	59
20	68
25	77
30	86

Anadromous salmonids spawn successfully in water temperatures ranging from 3.9° to 17.2°C. The range is lowest for steelhead (3.9° to 9.4°C) and highest for cutthroat (6.1° to 17.2°C). A sudden drop in temperature may cause all spawning activity to cease.

The eggs of most species incubate during the winter months. In the past it was believed that 4.5°C was the lower limit. Research has now found that pink and chinook salmon eggs can tolerate long periods of low temperature if spawning and initial embryo development occurred at temperatures above 6.0°C. The recommended range of incubation temperatures for chum, coho, pink, and sockeye salmon is 4.4° to 13.3°C; for fall, spring, and summer chinook salmon, 5.0° to 14.4°C.

The time young fish spend in their home streams before migrating to sea varies with species but is also influenced by water temperature. The growth rate, the ability to swim, capture and use food, and withstand disease are all affected by temperature. Temperatures above 25.8° are lethal for chinook, pink, sockeye, chum, and coho salmon. Under certain conditions steelhead trout can tolerate temperatures up to about 24°C. In general, all cold water fish stop growing at temperatures above 20.3°C.

Turbidity or sediment content

Although migrating adults will persist in swimming toward their home streams through turbid water, they will stop when silt loads get too high. One study reported that salmonids would not move in streams where sediment was more than 4,000 milligrams per liter. This is water that looks like soup or a mud puddle. (People usually stop fishing when silt reaches 50 milligrams per liter.) Turbid water also absorbs more radiation than clear water, and this may be an indirect cause of increased water temperatures that may stop migration. During the juvenile rearing period, high levels of suspended solids may abrade and clog gills, reduce feeding, and cause fish to avoid areas.

In general, scientists have found that streams with silt loads averaging less than 25 milligrams per liter will support good freshwater fisheries.

Dissolved oxygen

Although the requirements for concentrations of oxygen dissolved in the water vary with species and developmental stage, concentrations at or near saturation are recommended for all salmonids, with temporary reductions no lower than 5.0 milligrams per liter. Dissolved oxygen and water temperature are closely linked; the higher the temperature the less oxygen the water will hold, and the higher the temperature the more oxygen fish need.

Fish populations are estimated by using electric shocks to bring the fish temporarily to the surface.

Low amounts of dissolved oxygen may stop migration. In one study, the swimming speed of both adults and juveniles decreased sharply when levels dropped to 6.5 milligrams per liter.

Concentrations of dissolved oxygen in intragravel water must average 8 milligrams per liter to insure high survival of coho salmon and steelhead embryos. Embryos receiving less oxygen are likely to have longer incubation periods, and the resulting fry are apt to be smaller and weaker than fry incubated with high oxygen concentrations. A study using three concentrations of dissolved oxygen indicated that the juveniles tested functioned well with 7.75 milligrams per liter of oxygen. When oxygen was reduced to 6.00 milligrams per liter the fish developed initial symptoms of distress.

Water depth

Requirements for water depth are fairly well documented. For upstream migration, adults require minimum depths ranging from .12 meters for trout to .24 meters for the larger salmon. Measurements near active redds indicate minimum depths from .06 to .30 meters are selected for spawning.

Depth is particularly important during the juvenile rearing period because it influences production of aquatic organisms that are important food for salmonids. Most of these organisms are found in shallow areas typical of riffles. In one study, several species were found in water less than 0.3 meters deep. If other conditions are suitable, the areas that produce the greatest number of invertebrates are usually 0.15 to 0.9 meters deep.

Water velocity

Under certain conditions of channel constriction during snow melt and storm runoff, water may flow faster than migrating adults can swim—approximately 2 to 4 body lengths per second. Water velocities of 3 to 4 meters per second may retard upstream migration.

During spawning, preferred velocities range from a low of 11 to 72 centimeters per second for cutthroat trout to a high of 32 to 109 centimeters per second for summer chinook. Many salmonids prefer to spawn at the interchange between pool and riffle, where a downwelling current may help a fish maintain its position with a minimum of effort.

During rearing, stream velocity plays an important role in the distribution of aquatic invertebrates that are primary food for juveniles. Most invertebrates live in a thin layer of water 1/4 to 1/2 inch deep just above the bottom of the stream. Velocities there are near zero, but these invertebrates depend on water flowing immediately above the lowest layer for oxygen and other environmental needs. There, velocities of 0.15 to 1.22 meters per second are needed.

Streambed

The streambed or substrate provides the gravels which are essential for spawning, incubation, and the production of food during juvenile rearing. When adult fish select sites for redds, they are often selecting the incubation environment. The size of gravel chosen by different species depends to a large extent on size of the fish. Researchers have determined the particle size preference of different species by running samples of gravel from active redds through a series of sieves. When offered a choice of gravel size in artificial spawning channels, pink, coho, and spring chinook salmon select gravel from 2 to 10 centimeters in diameter. Sizes acceptable to all salmon species range from 1.3 to 10.2 centimeters. For smaller trout the range begins at .6 centimeters.

During incubation, permeability of gravel is vital. This factor determines subsurface water velocity, which is the single most important factor in delivering oxygen to the eggs and removing metabolic waste products. Researchers have concluded that fish production is greater in gravels with high permeability. Permeability is high (velocities up to 24,000 centimeters per hour) when sand and silt that can pass through an 0.833 millimeter sieve make up less than 5 percent of the bottom material. It is low (velocities less than 1,300 centimeters per hour) when fine sediment makes up more than 15 percent of the stream bottom.

Even though embryos may hatch and develop in gravel with excessive sand and silt, fry will not survive if they cannot emerge from the gravel. In one study fewer chinook salmon and steelhead fry emerged when sediments smaller than 6.4 millimeters made up 20 percent or more of the substrate.

The size of streambed material is also important. Areas with coarse gravel and rocks up to about the size of grapefruit provide a diversity of cover for streambed invertebrates that are food for fish. With larger rocks there are fewer invertebrates. The size of material on the stream bottom is also related to velocity; large rubble and boulders are associated with fast current, silt and sand with slow moving water.

Protective cover

Protective cover is important for adults waiting to spawn and especially for juvenile fish. Overhead cover and shade near stream margins are provided by riparian vegetation, turbulent water, undercut banks, and shadows cast by large debris and rocks in streams. Submerged cover is provided by aquatic vegetation, large rocks, and partially submerged logs and root wads incorporated in the streambed.

Overhanging vegetation and partly submerged logs provide cover for fish.

Some anadromous species enter freshwater streams months before they spawn, and since spawning areas are often on relatively open parts of streams, the fish are vulnerable to disturbance and predation. The availability of cover nearby may be a factor in the selection of spawning sites by some species. Researchers have speculated that the early spawners and large dominant fish may select areas by cover and that as these areas are taken, the late spawners and smaller fish are forced to use unprotected sites.

Juveniles are susceptible to predation from other fish and terrestrial animals and need places to hide. Newly emerged salmonids and some overwintering juveniles tend to hide under stones or among rocks and rubble on the stream bottom. Studies have shown that removing cover reduces juvenile populations and adding cover increases them.

Food sources

While the stream bottom produces the invertebrates that are the principal food for juvenile salmonids, the surrounding land is also important. Bits of vegetation that fall into streams provide food for the aquatic invertebrates. Terrestrial insects also fall from or are blown off shrubs, grass, and other vegetation into the water to become part of the drift that also provides food for fish.

Processes that shape habitat

Natural events like storms, fire, earth movements, and outbreaks of insects and disease on vegetation can make drastic changes in watersheds and streams. Sometimes these events improve habitat, as when heavy rainfall swells streams and flushes fine sediment from the gravels. Whether the effect is beneficial or detrimental depends somewhat on timing. For example, flushing and gravel redistribution that occurs while eggs are incubating can bury an entire generation or grind up eggs and newly hatched fry. The effects on habitat of natural events are the subject of the second report in the compendium.

An understanding of ways natural events modify habitat, combined with knowledge of habitat requirements—the subjects of the first two reports—together provide a foundation for predicting the effects of human activities on fish.

"We already know a good deal about the effects of removing streamside vegetation," Meehan says. "Streams exposed to sunlight will have higher water temperatures in summer, and lack of insulating canopy may lower them in winter. We have recently begun to quantify the importance of large woody debris in providing rearing habitat for juveniles, including pools they need for cover and the material that provides food for aquatic organisms. We have also learned that the very small headwater streams that dry up in summer provide spawning areas for thousands of salmon and steelhead in winter."

Since management activities—unlike natural events—can be planned to minimize adverse effects on habitat, the other 12 reports in the compendium will summarize present knowledge about the effects of specific management activities and suggest guidelines for protecting fish habitat.

The effects of forest roads on fish habitat are discussed in the third report of the series. The publication includes suggestions for designing, constructing, and maintaining road systems with minimal adverse effects on fish habitat. The primary adverse effects are increased sedimentation, changes in stream velocity, and obstructions to fish passage posed by bridges, culverts, and other structures. For example, a migrating adult is often near exhaustion after surmounting a difficult obstacle. If there is no resting area upstream the fish may be swept downstream and have to spend energy overcoming the obstacle a second time.

The effects of log processing mills and camps on fish habitat are reviewed in the fourth report. These effects are primarily the discharge of toxic effluents from pulp and paper mills and a reduction in the amount of dissolved oxygen in the water, resulting from decomposition of wood sugars in mill wastes. Toxicity and low levels of oxygen reduce the growth of fish and their ability to swim. In one study researchers found that when fish were exposed to sublethal concentrations of kraft effluent they reversed the flow of water past their gills. This activity, which researchers called "coughing," increased when concentrations of effluents were increased.

"It is important to realize," Meehan says, "that stresses on fish are cumulative and that relieving them may involve adjustments in many forest management activities." He expects the research program to continue to define more closely the habitat requirements of fish and the influences of land management on habitat. Ways to enhance and restore damaged habitat are also being studied.

Publications available

The first four publications in the planned compendium series, "Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Western North America," are now available from the Pacific Northwest Station. They are:

Habitat Requirements of Anadromous Salmonids by D. W. Reiser and T. C. Bjornn, General Technical Report PNW-96.

Impacts of Natural Events by Douglas N. Swanston, General Technical Report PNW-104.

Planning Forest Roads to Protect Salmonid Habitat by Carlton S. Yee and Terry D. Roelofs, General Technical Report PNW-109.

Processing Mills and Camps by Donald C. Schmiege, General Technical Report PNW-113.

Small streams and side channels provide important rearing habitat for juvenile salmonids.

Studies show strength of tree roots

by Marcia Wood, Pacific Southwest Station

Along the Pacific Coast, from northern California to Alaska, some of the most productive forest land occurs on some of the least stable slopes. On many of these sites, the strong roots of trees and shrubs add strength and stability to the soil, and help prevent the soil mantle from sliding down the mountainside.

Research at the Pacific Southwest Station's Redwood Sciences Laboratory in northwestern California is showing how rapidly the reinforcing properties of tree roots can deteriorate after a site is clearcut. Further, the research is determining how long it takes planted tree seedlings or invading brush to rebuild the soil-root matrix that existed before logging. And, the studies are comparing the strength of the roots of different species of trees and shrubs. The work is underlining the importance of root strength as a factor that must be considered in assessing landslide risk and in evaluating any forest management activity—such as logging—that would alter the soil-root matrix.

In charge of the studies is Robert R. Ziemer, research hydrologist at the Redwood Sciences Laboratory in Arcata. Ziemer says plant roots can play "a critical role in maintaining the stability of steep slopes that have shallow, cohesionless soils." He explains, "Vertical roots can anchor a shallow soil mass to fractures in the bedrock. Horizontal roots provide long, fiberous binders that can interlock and tie the hillside together laterally. When the forest cover is removed, these roots deteriorate, and much of the soil strength is lost."

International studies

One of Ziemer's collaborators, Geologist Doug Swanston of the Pacific Northwest Station, Juneau, Alaska, says root strength is something that has been largely ignored in the U.S. He points to practices in Czechoslovakia and Hungary, where foresters use different tree species "to get a degree of control over landslide occurrence." Researchers in Russia, Canada, New Zealand, and Japan are also investigating the soil-binding properties of tree roots. At the Redwood Laboratory, Ziemer has worked with translators to prepare English-language summaries of some of the most important research reports from Japan.

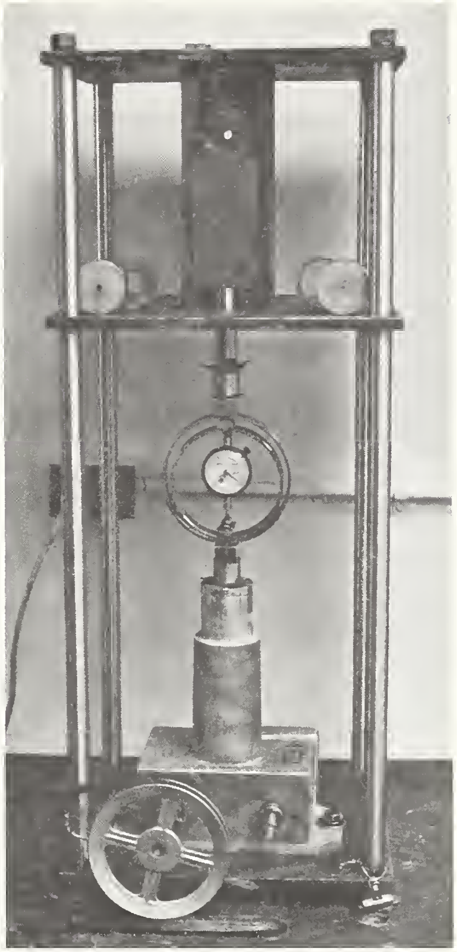
Although other researchers in the U.S. are studying the role of tree and plant roots, Ziemer probably has the most comprehensive data on this topic. Over the past several years, his field crews have worked at sites ranging from the Six Rivers National Forest in northwestern California to the Tongass National Forest in southeastern Alaska. They have excavated more than 500 tons of soil and, from this, have extracted more than 5 tons of roots. The roots have been shipped to the Redwood Laboratory, where they have been washed, sorted into diameter and age (years since logging) classes, oven-dried, and weighed. By comparing the measurements from cutblocks of various ages, Ziemer has shown how the amount of roots in the soil changes in the years following logging.

Other roots have been sheared with a laboratory machine that Ziemer designed and built. These measurements indicate the strength of roots of various forest species.

And, to examine yet another aspect of root strength, soil blocks—which include roots—have been sheared in the field, using a portable shear box that Ziemer developed. These measurements show the strength of the soil-root matrix.

All of these data will be used to develop a model of how slope strength changes in the years following logging. The model can be used—along with other guides—to predict how logging might affect root strength and the stability of fragile, slide-prone slopes.

Ziemer's contributions to date have been to provide preliminary information on root strength in various forest types—encompassing some 30 different tree and brush species—in California, Oregon, and Alaska. He has presented workshops for foresters, engineers, geologists, hydrologists, and others in California and the Pacific Northwest. His findings have been used, along with other data, to modify timber management plans on National Forests and privately owned timberlands on the West Coast. And, he has redesigned and improved equipment used to shear roots in the laboratory and in the field.



The laboratory shear device measures the amount of force it takes to shear individual roots.

Preliminary results

Although much of his data is still being analyzed, Ziemer has some preliminary results from several of the areas he has studied. One of these areas is the vicinity of Staney Creek on the Prince of Wales Island in Alaska. There, Ziemer and Geologist Swanston compared western hemlock and Sitka spruce roots in uncut areas to roots in areas that had been clearcut either 2, 4, 6, or 10 years before the study.

The researchers collected root segments, each approximately 12 centimeters long, from the mineral soil. The roots were grouped into 6 diameter classes of 2, 5, 10, 17, 25, and 50 millimeters (without bark), and were then sheared in the laboratory.

For hemlock, spruce, and red elderberry (a shrub that invades cutover sites), Ziemer and Swanston found that the smaller roots lost strength very quickly in the first 2 years after logging. Hemlock roots were more resistant to loss of strength than the Sitka spruce roots: 2 years after logging, hemlock roots smaller than 25 millimeters in diameter lost only about one-third of the average strength, while Sitka spruce lost about one-half the average strength. The large hemlock roots (50 mm in diameter) didn't lose any strength during the first 6 years after cutting. However, over the next 4 years, these roots lost 50 percent of their strength. The pattern was similar for the large Sitka spruce roots. Roots 50 mm in diameter retained their strength for the first 6 years after logging, then lost 87 percent of their strength over the next 4 years.

Surprisingly, red elderberry shrubs contributed to soil strength. Although the smaller elderberry roots, such as those that were 2 mm in diameter, were much weaker than Sitka spruce or hemlock roots of the same diameter, the larger elderberry roots (17 mm in diameter) were comparable in strength to the spruce and hemlock roots in this size class.

Mixed-conifer sites

At cutover mixed-conifer sites in the Klamath Mountains of northern California, Ziemer's work showed that invading brush species can help keep a fragile slope from falling apart after logging. These results were based on laboratory and on-site tests of roots sifted from 103 soil blocks. The soil blocks were excavated from cutover sites that had been logged anywhere from 3 to 24 years before the study. Roots from an uncut, old-growth stand were measured for comparison.

Ziemer found that two of the common hardwoods, golden chinkapin and Pacific madrone, and two shrubs, Pacific red elder and snowbrush ceanothus, had stronger roots than the conifers (white and red firs, sugar and ponderosa pines, and incense cedar). The snowbrush roots, which were a major component of the cutover sites, were about twice as strong, on the average, as pine and fir roots. For example, snowbrush roots 2 millimeters in diameter were about 1.35 times as strong as conifer roots; the 50 millimeter brush roots were about 3.76 times stronger than fir or pine roots.

By comparing the strength of roots that remained on the various ages of cutblocks, Ziemer determined that, within 2-3 years after logging, about half of the original reinforcing strength of the roots was gone. After 8 years, three-fourths of the strength was lost. After 25 years, essentially all of the reinforcement by dead roots was lost.

When brush began to invade the cutblocks, the site recovered much of its original reinforcement. "Brush can bring a site back up to a level that is equal to 70 percent of the reinforcing strength of an uncut stand," Ziemer explains. "But, as the brushfield ages and the decay of the conifer root progresses, root reinforcement will decrease." He points out, "If the transition from a cutover site, to a brushfield, to a conifer forest, is gradual, the reinforcement by roots will slowly return to that of an uncut forest. If brush is killed in an attempt to establish the conifers more quickly, however, the strength of the soil-root matrix will probably drop rapidly. It may be several years before the dead roots of the brush are replaced by the small roots of young conifers. Thus, from the standpoint of soil and slope stability, invasion by brush may be desirable."

Equipment modified

The laboratory and field equipment that Ziemer designed for the root strength analyses represents modifications of models developed by others. Ziemer's portable shear box measures the amount of force that it takes to break the soil-and-root fabric. An earlier model measured the shear resistance of the soil and of those roots that grow down through the soil profile. Ziemer's version gauges shear resistance of the soil and the horizontal roots. Ziemer believes that these horizontal roots are "probably more important than the vertical ones." He explains, "the horizontal roots can connect weak areas to stable portions of the slope, and can strengthen unstable slopes in other ways, as well."

The laboratory shear device that Ziemer designed measures the amount of force it takes to shear individual roots. The stress is applied to each root at the rate of 3.6 centimeters per minute. These shear strength measurements can be converted into measurements of tensile strength, using a formula that Ziemer developed.

Tensile strength is an indication of how much force it takes to pull a root apart, from both ends. This approximates the tearing action that occurs in nature when a slope begins to give way. In developing the conversion formula, Ziemer worked with a tensile strength machine that was built by Edward R. Burroughs of the Forest Service and Byron R. Thomas of the Bureau of Land Management. The major drawbacks with this and other tensile strength machines are that they are limited in the size of the roots that they can accommodate, and that they are time-consuming to use. Currently, tensile strength machines can't measure roots larger than 15 millimeters in diameter, while Ziemer's machine can accommodate roots up to at least 50 millimeters. It can take as long as 15 minutes to test a root on a tensile strength machine; the shear stress machine only takes about 30 seconds.

Ziemer believes that the combination of the shearing machine and conversion formula offers the best of both approaches, and provides "excellent predictions of root tensile strength."

Limits to concept

The concept of root strength does not apply to every acre of forest land on every naturally unstable slope. Instead, it is most applicable to sites where the soil is shallow and lacks cohesion. Thousands of square miles of forest land from Alaska to California fit this description. Contributing further to the instability of this region is the fact that it is located at the margins of continental and oceanic plates. The plates are continually colliding, shifting and grinding, and uplifting the land. "This activity, combined with rapid erosional processes, has produced a steep and youthful topographby," Ziemer says. "Many of these steep slopes are landslide-prone. The landslides may take the form of shallow-seated mantle slides—failures in which the soil mantle gives way to the natural stresses acting upon it. The binding action of tree and plant roots provides some resistance to the sliding forces that cause shallow-seated slides."

This shallow-seated mantle slide occurred in a hemlock-Sitka spruce stand on the Tongass National Forest, southeastern Alaska.

"Where there are deep zones of slope weakness, root strength can't keep a slope from sliding. Landslides on such sites may originate hundreds of feet beneath the rooting zone, and may be several miles across. In these situations, the sliding forces overwhelm the resisting forces provided by the vegetation."

Shallow-seated mantle slides are comon in all of the coastal forests Ziemer has studied. On the Siuslaw National Forest in Oregon, for example, more than 200 of these slides occurred in one winter!

Findings used

The research has attracted considerable interest. Paul Brouha, senior fisheries biologist for the Shasta-Trinity National Forest in northern California, says, "Ziemer has given us substantial insight into the strength of the roots of different brush and timber species." George Bush, soil scientist for the Siuslaw National Forest, says that the research is a key element in assessing landslide risk on the Forest. "Root strength is the primary variable that we use to show that we are getting an acceleration of landsliding—over and above the natural landslide rates—after clearcutting. On the Siuslaw, many sites that are highly productive have a high landslide risk. Ziemer's work gives us the kind of backup we need—proof of the potential for landslide occurrence following clearcutting." Bill Hicks, engineering geologist on the Rogue River National Forest, Oregon, describes root strength research as "a needed piece of the stability data package required for correct land management prescriptions." He says that Ziemer's work has "added to the accumulating body of knowledge regarding the stability reponse of the soil mantle to logging," and has "helped convince forest managers of the fragility of mountainous slopes."

For further reading

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Giving the land back to nature

by Louise Kingsbury, Intermountain Station

Southeastern Idaho's sagebrush deserts and forested mountains house prime fishing, hunting, and grazing. But this area is also a big phosphate producer, and several large mines dot the landscape. Mining and its associated activities have taken a heavy toll on this part of the country. Huge waste dumps, seemingly incapable of supporting any plants or animals, mar the view. Massive soil runoff creates water pollution for miles around.

Five years ago little was being done to clean up the waste dumps. Today, application of extensive hydrological and revegetation research is transforming these dumps into foliaged wildlife habitat and eliminating water pollution.

Knowing the amount of moisture at a waste dump helps researchers in revegetation efforts. Precipitation from snow and rain is measured. The degree of ground water saturation is determined with a nuclear measuring device. Such measurements help indicate ground stability or erosion problems of spoils just mined or already revegetated.

"I would like to look at a hill and not know whether it was mined or not," said Paul Packer, project leader of the Mine Spoil Reclamation Research Work Unit, before his recent retirement. The work unit is at the Forestry Sciences Laboratory in Logan, Utah. Also involved in the research is the Shrub Improvement and Revegetation Research Work Unit at the Shrub Sciences Laboratory in Provo, Utah. Both units are part of the Intermountain Forest and Range Experiment Station.

Two problems

Packer says the reclamation research concentrates on solving two pressing and related problems in phosphate rehabilitation. One is erosion and mass instability caused by steepness of waste dump slopes and accumulation of pockets of saturation, or ground water, within the dumps. Forest hydrologist Eugene E. Farmer uses nuclear measuring devices and computer and plastic models to determine ground instability problems and to illustrate to miners how to best construct waste dumps.

The other problem is revegetation of the barren and nutrient-poor materials to reduce erosion and restore wildlife habitat. Research forester Bland Z. Richardson stresses the practical application of revegetation research by actively helping industry restore the spent earth. Several major phosphate mining companies, with the help of Forest Service personnel, are now restoring the waste dumps located on public lands.

Included in these reclamation projects is the Ballard Mine (Monsanto Chemical Co.), where this Forest Service research began. Results were later applied to other Idaho mines, including the Wooley Valley Mine (Stauffer Mining Co.), Maybe Canyon Mine (Beker Industries), and Conda and Gay Mines (both J. R. Simplot Co.).

A billion tons of ore

These mines and other phosphate areas in southeast Idaho hold one of the world's richest known phosphate reserves. More than 1 billion tons of potentially recoverable ores have been identified here. The area, centered around Soda Springs, Idaho, comprises 90 percent of the identified phosphate reserves in the 130,000 square miles of the western phosphate field (Idaho, Wyoming, Utah, and Montana), and about 35 to 50 percent of all the phosphate reserves in the United States. The annual phosphate production from southeast Idaho is about 5.5 million tons, mostly from surface mines high on steep mountainsides.

Phosphate is valuable for its many industrial and commercial uses. It is used primarily for fertilizer and detergents and secondarily for such things as toothpastes and plastics. A phosphate byproduct, vanadium, is added to steel to make some of the world's finest cutlery.

There is no known substitute for phosphate, according to Packer. "But southeastern Idaho has 125 years of phosphate mining left. That means a great challenge for making these lands habitable after industry has mined them."

Packer points out that this part of the United States is known for its excellent wildlife habitat, especially for sagehen, sandhill crane, moose, elk, and cutthroat trout. Mining, in some cases, adversely affects wildlife habitat, and erosion from dumps frequently contaminates streams and lakes, harming aquatic habitat and drinking water.

The Intermountain Station began phosphate rehabilitation research in 1972 when it joined existing efforts on the Caribou National Forest. The cooperative work broadened in 1974 under the Surface Environment and Mining (SEAM) program. Intermountain Station researchers were particularly concerned with waste dumps.

Steps in rehabilitation

Constructing a stable, vegetated mine dump requires solving several major problems. Eugene Farmer attacks the first problem of dump stability using detailed measurements of ground water at various depths on one dump site. The resultant computer models recently served as the pattern for a multilayered plastic model. This three-dimensional model graphically demonstrates subsurface soil problems. The model is used in training and in meetings with industry.

North- and east-facing slopes retain heavy winter snowpack late into the spring, resulting in potentially high erosion hazards. At a mine dump, such slopes require immediate ground cover to hold the barren earth in place.

"We can take our research results to industry and show how problems can be solved long before a waste dump is constructed," says Farmer. "How to build the dump is the key."

On an existing dump, reshaping a slope is the first step in successful rehabilitation. Leveling the dump to something less than a 33 percent grade makes revegetating and land stabilizing easier.

Revegetation is next. Richardson points out that for maximum stability, ground cover must be planted on the entire dump in the first year. The degree of revegetation success depends on adequate site preparation, which includes ripping, harrowing, fertilizing, and planting.

According to Richardson, sterile spoils and the surface temperature of dark spoils on south-facing slopes are the biggest obstacles to revegetating phosphate dumps. Temperatures as high as 174° F have been recorded on these slopes. Researchers studied some 500 plant species in the quest for those that would best overcome these obstacles. Temperature problems have been solved by choosing the correct time for planting, method of planting, manipulation of spoil, and proper selection of plant species.

"One of our goals is to restore the land to productivity," says Richardson. "This especially means selecting plants that add organic matter and nutrients to the spoils. Legumes, for instance, add nitrogen."

At Idaho's Ballard Mine, vegetation in experimental plots is assessed for species composition and density.

Research results

The result of the research is that even on hot, steep, south-facing slopes, lush vegetation now grows and the ground is stabilizing. Erosion that once removed as much as 500 tons of earth a year off a mine dump is now curbed through vegetation that includes grasses, sagebrush, and legumes, and on north-facing slopes, mixed conifers and shrubs.

On one study site, for example, the erosion rate averaged 85 tons per acre during the first year following construction. Workers immediately revegetated the dump, and erosion rates during the second year dropped dramatically to an average of 4.4 tons per acre—about a 95 percent reduction. As the plants take a firmer grip on the earth in succeeding years, erosion should not exceed a ton or so per acre, much closer to the land's condition before mining.

Research results have been distributed to industry and other government agencies through personal contact, as well as meetings, symposia, and publications. The researchers are also working on a videotape "how to" program centering on rehabilitating phosphate dumps but also touching on other mining types. The 30-minute, color tape, produced by the Colorado School of Mines, will be released by early summer 1981. It is aimed at reclamation specialists in industry and at land managers in charge of evaluating reclamation techniques.

The research in southeastern Idaho also provides recommendations on revegetation techniques in other mining operations, including coal, heavy metals, oil shale, and barite. Over 60 mines, including phosphate, operate in the Western United States, with nearly 500 people involved in reclaiming the waste dumps.

Research results and recommendations, and the instructional material, give to industry and government the techniques needed to fulfill Federal and State laws requiring rehabilitation of mined lands.

Roger R. Bay, director of the Intermountain Station, says industry has taken readily to the Station's rehabilitation techniques. "An increasing awareness of the value of public and private lands has placed a stronger emphasis on their restoration to true multiple use," says Bay. "The result speaks well for government and industry concern for the future."

Leafy spurge —Scourge of the West

by Matthew McKinney, Rocky Mountain Station

Leafy spurge (Euphorbia esula L.) is a tenacious perennial weed infesting nearly 2.5 million acres of range and croplands in the U.S. Despite millions of dollars spent annually on control efforts, the weed has spread steadily since its introduction around the turn of the century.

Leafy spurge originated and is widespread in continental Europe. It extends through central Russia and into Siberia. Seed is believed to have been first brought to the U.S. in shipping ballast. The first herbarium specimen was collected here in 1827. Since then, it has spread like a plague throughout several states, with a concentration center in the northern Great Plains and southern Canada.

Scientists at the Rocky Mountain Station's Forest Research Laboratory at Rapid City, South Dakota, are part of a multi-agency effort to find efficient and effective ways to control the weed.

Dan Noble, research forester at the lab, says, "Leafy spurge is a problem on tree belts, parks, waterways and roadsides. The real economic impact, however, is on crop and rangelands." The weed displaces useful forage and, if unchecked, will take over as the dominant species on pastures and ranges. It also invades croplands, especially uncultivated fields, and can cut crop yields dramatically.

Leafy spurge is a poisonous plant and, externally, causes dermatitis to man and animals. Taken internally, it causes scours and weakness in cattle and may cause death. Sheep become sick by eating mature plants, but are less affected by small plants. They have also been used on a limited scale for control. Livestock will eat dried plants in hay, but usually avoid eating growing plants except under poor range conditions.

Why is leafy spurge such a problem, and why haven't control efforts been successful? One factor is the root system. Each plant has an extensive root-rhizome network that occupies a large volume of soil. Roots have been measured down to 15 feet in depth. The plant is able to withstand drought conditions, and can store a three-year supply of nutrients in its roots. The roots and rhizomes are woody and tough, and if cut, have great ability to produce new shoots from various depths. In addition, the plant spreads rapidly. One seedling of the weed can spread to occupy an area of soil 24 feet in diameter in 4 years.

Leafy spurge has taken over this once excellent pasture in Wyoming.

The weed has yellowish-green flower-like clusters that are pollinated primarily by insects. Seed stalks are prolific, producing up to 150 seeds each. Under favorable conditions up to 99 percent of the seeds will germinate.

Control efforts

Farmers, ranchers, government agencies, and others spend several million dollars annually, primarily on herbicides, fighting leafy spurge. Chemicals currently being used include 2,4-D, picloram and glyphosphate. However, all have had only limited success. Not only can these herbicides be damaging to existing grasses, forbs and other beneficial plants, but they are expensive and may not be cost effective on a large scale.

Biological control is another method gaining interest, but is still in the early stages of development. There are several species of insects and a rust (Urormyces striatus) that attack leafy spurge. While most of these organisms are found in Europe, they are from a climate similar to the Canadian and U.S. prairies, and hold promise for future use. Plans are now underway to test several of these insects and disease agents on leafy spurge.

Noble says controlled burning has been used successfully to battle the weed. He says that a good, hot fire will kill most of the seed in a stand, but top growth should be killed first with a herbicide for maximum effectiveness.

Noble believes that an integrated regional control program, backed by state and federal governments is needed to effectively control leafy spurge. "To initiate a good regional control program," he explains, "we first need a complete inventory of the weed, which should include land ownership, type of habitat and terrain infested, and intensity of the infestation. Techniques to evaluate results of control treatments are also necessary."

A flowering leafy spurge plant.

Root nodes of leafy spurge are prolific and very resistant to chemicals.

Field equipment, such as this herbage meter helps measure the production and spread of the weed.

Aerial surveys

This is where Rocky Mountain Station scientists with the Resources Evaluation Techniques Program at Fort Collins, Colorado offer help. They are studying the feasibility of using aerial photography for inventorying spurge and evaluating treatment methods. Several flights have already taken place using both color and infrared at different photo scales. These scales and film types are currently being tested to determine which combination is best suited for large area surveys, quantitative site measurements, inventory and monitoring.

As leafy spurge continues to spread, more and more state and federal agencies are joining forces against the weed. A steering committee was recently named to help develop a program package for needed attack on leafy spurge. The program involves research, extension, education and improved coordination between the agencies.

Several states are carrying on their own research and treatment programs. In 1978, the Wyoming legislature passed a Leafy Spurge Control Act, launching a multi-million dollar program that has seen over 18,000 acres treated and 2,500 acres retreated. Other states are considering similar action.

Noble says, "We still could be several years away from an integrated large-scale treatment program that offers full success in controlling leafy spurge. However, through continued research, proper land management, public education, and the development of a regional control plan, leafy spurge may eventually become a problem of the past."

New publications

Single copies of publications referred to in this magazine are available without charge from the issuing station unless another source is indicated. When requesting a publication, give author, title and number.

Organic debris in Maybeso Creek, Alaska

Events following logging in the Maybeso Creek drainage in southeast Alaska emphasize that natural accumulations of large organic debris play an active role in the form and structure of stream channels. A comparison of conditions found during a ground survey in 1978 after the watershed was logged, and conditions shown on earlier maps, indicates that timber harvests from 1953 to 1960 caused extensive changes in the stream channel. Although some of the changes were caused by equipment operating in the stream, most were related to the reduction of accumulations of large woody debris.

Before logging, sparse accumulations of large debris were scattered throughout the stream. During logging, all major concentrations of natural debris were affected. Large amounts of floating logging debris were sieved by the stable natural debris until massive, unstable jams were created. These were washed out by annual autumn floods. Ten years after logging, there were fewer accumulations than in 1949 before logging. The removal of old-growth forest along the streambank has effectively eliminated the source of new large organic debris. Except in the few remaining uncut areas, no new large material has entered the stream. Present channel morphometry (form and structure) appears to be determined by stream bank and bedrock formations. Small, young hemlock and alder do not have the same effect on the channel as did old-growth spruce and hemlock.

Details, including maps of the debris in the creek, are provided in *Evolution of Large, Organic Debris After Timber Harvest: Maybeso Creek, 1949 to 1978* by Mason D. Bryant, General Technical Report PNW-101. Copies are available from the Pacific Northwest Station.

Air pollution and forests reviewed

Results of recent research on the effects of air pollution on forests are summarized in a new publication from the Pacific Southwest Station. *Proceedings of Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems,* General Technical Report PSW-43, is a collection of 28 papers and 29 poster presentations from this June 1980, conference.

The reports cover the major pollution problems of two climatic regions—the world's temperate forests, including those of the U.S., Canada, Japan, northern Europe, and other areas; and the Mediterranean-type regions, including the Mediterranean Basin, southern California, southwestern Australia, central Chile, and southern Africa.

Studies of short- and long-term effects of such pollutants as ozone, sulfur dioxide, nitrogen oxide, and hydrogen fluoride are described by researchers from throughout the U.S. and several foreign countries. Summaries of the effects that acid rain has on forests and lakes are presented by scientists from the East Coast of the U.S. and from northern Europe, two areas where this problem is severe. Other researchers detail the effects of pollutants on insects, birds, lichens, and other forest life.

One of the main purposes of the conference was to evaluate the use of computer models for simulating the impact of pollution and for predicting future pollutant damage. These predictions are needed in order for regulatory agencies to set standards of air quality. Problems with current models, and suggestions for their improvement, are presented in several of the papers.

Copies of the *Proceedings* may be requested from the Publications Section, Pacific Southwest Station.

Nongame bird proceedings

Proceedings entitled *Management of Western Forests and Grasslands for Nongame Birds* is now available from the Intermountain Station. The 36 papers came from the fourth and last workshop in a series whose goal was to solve the problems of meeting avian habitat needs while managing other forest resources.

Forest Service Chief Max Peterson, in his keynote address in these proceedings, emphasizes the need for a "completely integrated wildlife program." He notes that the proceedings help National Forests in their land management plans and in meeting Resources Planning Act requirements.

"Everything we do as resource managers will benefit some species, be detrimental for some, and, perhaps, not even affect others," says Peterson. "The key is to plan for diversity of both plants and wildlife."

The workshop in Salt Lake City, Utah, in February 1980 focused on the state-of-the-art of nongame bird research and management in western States. Previous workshops looked at the special circumstances of other ecoregions. The workshop series was the outcome of a 1975 symposium where avian ecologists and forest resource managers met to discuss their common concerns. Participants in the series included representatives of the U.S. Department of Agriculture, U.S. Department of the Interior, and several wildlife associations.

You may obtain your copy of the 535-page proceedings from the Intermountain Station. Ask for General Technical Report INT-86 FR-25.

Classifying vegetation in Alaska

One thing Alaska has needed is a unified, statewide system for classifying vegetation to coordinate the many divergent systems used over the years by groups and agencies to map and inventory vegetation. A hierarchical system based on the characteristics of vegetation has now been proposed.

The classification system has five levels of increasing complexity. The first, or broadest, level has five categories: forest, tundra, shrubland, herbaceous vegetation, and aquatic vegetation. For each of these broad categories there are four additional descriptive levels. The breakdown for forests, for example, is conifer, deciduous, and mixed. The third level classifies these three types of forest as open, closed, or woodland, depending on the amount of canopy cover. The finest level of resolution lists over 400 plant communities by the dominant species in the tree, shrub, and herb layers.

The classification was first drafted in 1976 and has been reviewed extensively by scientists from public agencies and universities. The system is designed to be revised and refined as new information becomes available.

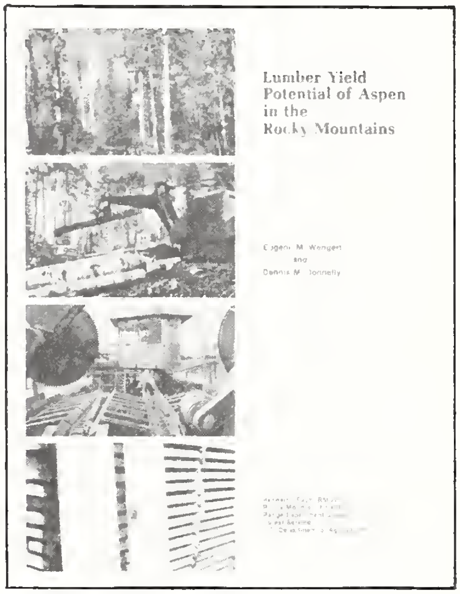
A new publication explains details of the classification system: *A Preliminary Classification System For Vegetation of Alaska,* by Leslie A. Viereck and C. T. Dyrness, General Technical Report PNW-106. Copies are available from the Pacific Northwest Station.

Increasing and optimizing aspen harvests in the Rocky Mountains

Grading methods are being evaluated to assess the potential of standing aspen timber and saw logs for conversion into wood products. These grading systems allow for separation of trees and logs into different levels of volume and dollars value recovery.

Recent surveys show the Rocky Mountain states have more aspen sawtimber (more than seven billion fbm of sawtimber) than any other area in the United States. While only 10 million board feet are now annually harvested, as much as 60 million board feet could be cut for optimum management of the species.

Since aspen is a softwood, tree and log grades developed for hardwoods are not appropriate for estimating lumber yields. In addition, lack of information on the lumber recovery potential of aspen in the Rocky Mountains and unfamiliarity of the possible uses for aspen contribute to underutilization.



Scientists at the Rocky Mountain station are working to relate lumber recovery to characteristics of aspen stands. Their research has indicated the importance of lumber volume and grade recovery in relation to visual attributes of downed logs and standing trees.

If you would like to know more about these management techniques, contact the Rocky Mountain Station and request *Lumber Yield Potential of Aspen in the Rocky Mountain,* Research Paper RM-227, by Eugene M. Wengert and Dennis M. Donnelly.

Fire ecology of Montana habitats

An Intermountain Station paper summarizes the available fire ecology and management information that applies to habitat types of the Lolo National Forest, but is applicable to many of these habitats throughout western Montana.

Fire Ecology of Lolo National Forest Habitat Types is written by Kathleen M. Davis, Bruce D. Clayton, and William C. Fischer.

The authors arranged the habitat types into 10 "Fire Groups" based on the response of the tree species to fire and the roles of these species during successional stages. They review the literature on fire and succession and present a diagram of the role of fire on all the habitat types in each Fire Group. Based on such information, the authors then suggest how to develop fire management plans that support land and resource management objectives.

Contact the Intermountain Station for copies of General Technical Report INT-79 FR-25.

Guide lists sources of economic data

More than 300 different sources of economic data that are useful in wildland planning and management are listed in a new directory from the Pacific Southwest Station. The publication is *Economic Data for Wildland Planning and Management in the Western United States: A Source Guide,* General Technical Report PSW-42.

The *Guide* is an introduction to published reports, computerized data bases, and other compilations of data that are provided by Federal and State agencies, colleges and universities, private organizations, and other groups. Sources of data about costs, returns, supply and demand, and other economic factors, are presented for six wildland management activities—outdoor recreation and wilderness, wildlife and fish, range, timber, land and water, and minerals and energy. The brief description of each data source includes the title, the address of the author or issuing agency, and comments about the types of information the source provides.

Federal sources, for example, include *Western Economic Indicators,* issued by the Federal Reserve Bank of San Francisco; the Bureau of Land Management's *Public Land Statistics;* and the U.S. Department of Labor's *Chartbook on Prices, Wages, and Productivity.*

Typical of the State sources is *Alaska Economic Trends,* issued by the State's Department of Labor; or *Montana Agricultural Statistics,* an annual compilation of crop and livestock production data from the Montana Department of Agriculture.

University sources include *Colorado Ski and Winter Recreation Statistics,* issued annually by the University of Colorado's Business Research Division; or the *Survey of Hunters in Oregon,* prepared every 2 years by Oregon State University's Survey Research Center.

Data sources maintained by private organizations include *The Sporting Goods Market,* an annual guide issued by the National Sporting Goods Association; or *Western Lumber Facts,* issued monthly by the Western Wood Products Association.

The 125-page *Guide* was prepared by two Pacific Southwest Station cooperators, Eric Eisenman and Lee C. Wensel; and two former Station researchers, Thomas W. Stuart and Edward C. Thor. Copies of the publication are available from the Pacific Southwest Station.

Make your own residue photos

Researchers at the Pacific Northwest Station have prepared guidelines to help managers make their own photo series to illustrate the amount and character of dead and down residues. The guidelines provide complete instructions for selecting, photographing, and inventorying examples of different levels of residue, to supplement photo series already published.

Authors Wayne G. Maxwell and Franklin R. Ward have written three previous publications which combine photographs of residue with detailed descriptions to illustrate a range of residue levels. With these tools, managers find it easier to estimate the amount and characteristics of residue, predict the amount of residue from a planned harvest, and communicate with other managers and specialists about residue.

Photo Series for Quantifying Forest Residues in the Coastal Douglas-fir-hemlock Type and Coastal Douglas-fir-hardwood Type, General Technical Report PNW-51, is out of print but may be available through library services. *Photo Series for Quantifying Forest Residues in the Ponderosa Pine and Associated Species Type, Lodgepole Pine Type,* General Technical Report PNW-52 is available from the U.S. Government Bookstore, 915 2nd Ave., Rm. 194, Seattle, Washington 98174. *Photo Series for Quantifying Forest Residues in the Sierra Mixed Conifer Type and Sierra True Fir Type,* General Technical Report PNW-95, and the newest one, *Guidelines for Developing or Supplementing Natural Photo Series,* Research Note PNW-358, are available from the Pacific Northwest Station.

Recreation and wildlife: A bibliography

Hikers, cross-country skiers, photographers, and other recreationists visit backcountry areas in numbers that have caused wildlife to cease using otherwise desirable habitat. And while studies on recreational impacts on campsites, trails, and vegetation frequently provide information for management plans, the effect of backcountry recreationists on wildlife has been given less attention. This is probably because most wildlife species are not fixed to the spot (as are plants), and therefore recreational effects are not immediately evident.

The Intermountain Station has published a bibliography that is, in part, a response to the concerns of land managers and recreationists who appreciate the value of wildlife and wish to reduce the unintentionally harassing effects of increased people-wildlife encounters. The bibliography contains 232 references concerning these encounters.

The criteria for selecting papers were that they describe the interaction of recreationists with some species of wildlife in a natural setting, or present research findings and techniques that could be used to reduce people's impact on wildlife.

Recreation (skiing, backpacking, hiking, photographing, and birdwatching) was considered "backcountry" where it affected wildlife in natural, undeveloped areas, whether the areas were wilderness as defined in the 1964 Wilderness Act, or lightly roaded. The emphasis, however, was on lands that were not heavily used by motorized vehicles.

Impact of Backcountry Recreationists on Wildlife: An Annotated Bibliography, compiled by Catherine H. Ream, is available from the Intermountain Station. Ask for General Technical Report INT-84 FR-25.

Managing ponderosa pine in the Southwest

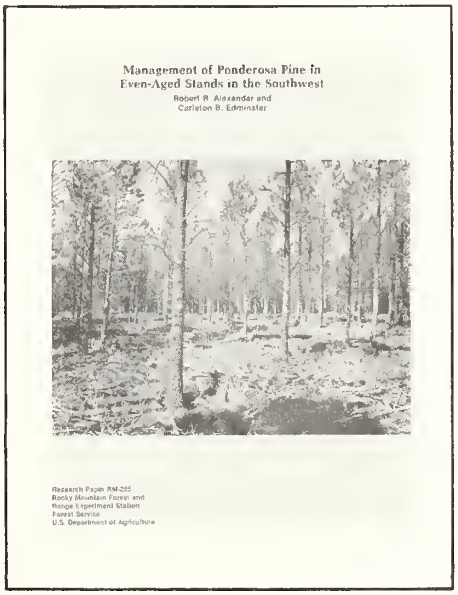
Ponderosa pine occupies the largest area of commercial forest land in Arizona and New Mexico. How these forests are managed affects lumber production, wildlife habitat, livestock forage, watersheds, recreation and scenic splendor.

With intensified resource management, managers are concerned with quickly regenerating cutover areas, increasing the growth rate of a new stand by control of stand density, and improving quantity and quality of yields by periodic thinning to maintain stocking control and growth rates while reducing mortality.

Potential production of ponderosa pine stands is the theme of a recently published Research Paper. Scientists at the Rocky Mountain Station have utilized an existing computer program, RMYLD, to simulate stand density, site index, age and thinning schedule for southwestern ponderosa pine forests in order to optimize multiple use tradeoffs.

These estimates will help land managers maintain the productivity of a ponderosa pine forest under an even-aged management system while producing acceptable multiple use tradeoffs.

If you would like a copy of the paper contact the Rocky Mountain Station and request *Management of Ponderosa Pine in Even-Age Stands in the Southwest,* Research Paper RM-225, by Robert R. Alexander and Carleton B. Edminster.



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